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Time Is Money, But How Much? The Monetary Value of Response Time for Thai Ambulance Emergency Services

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ABSTRACT

Objective: To calculate the monetary value of the time factor per minute and per year for emergency services. **Methods:** The monetary values for ambulance emergency services were calculated for two different time factors, response time, which is the time from when a call is received by the emergency medical service call-taking center until the response team arrives at the emergency scene, and operational time, which includes the time to the hospital. The study was performed in two steps. First, marginal effects of reduced fatalities and injuries for a 1-minute change in the time factors were calculated. Second, the marginal effects and the monetary values were put together to find a value per minute. **Results:** The values were found to be 5.5 million Thai bath/min for fatality and 326,000 baht/min for severe injury. The total monetary value for a 1-minute improvement for each dispatch, summarized over 1 year, was 1.6 billion Thai baht using response time. **Conclusions:** The calculated values could be used in a cost-benefit analysis of an investment reducing the response time. The results from similar studies could for example be compared to the cost of moving an ambulance station or investing in a new alarm system.

Keywords: cost-benefit, emergency medical service, medicine, response time.

Introduction

It is reasonable to say that all efforts should be made to decrease the time factor in the emergency alarm chain from calling to taking the call, to dispatching, to getting ready to leave, to driving to the injured people or people involved in the accident, to taking care of the injured or suppressing the fire, and to getting the injured to the hospital. However, should all efforts be made solely to decrease the time factor? Such efforts are costly, and there are other health matters that investments could be done in: better ambulances with more technical equipment, more training of the staff, better hospitals, provision of self-help equipment, and so forth. An economical way of dealing with this problem of the public sector is to perform cost-benefit analyses. The cost side of such an analysis is quite unproblematic. It consists of costs for new equipment, staff education, and so forth. The benefit side, however, is more problematic. For example, if the emergency sector intends to invest in a new alarm technology that could save 1 minute in response time for all responses, how much will such an investment lead to in benefits measured in economic welfare terms? Not only must the effect of a changed response time, measured in fewer fatalities, injuries, and illness, be found, but this change should also be measured in monetary units.

The purpose of this study was to find a monetary value for the time factor of emergency responses in Thailand. It is not a cost-benefit analysis because it considers only the benefit side of the time factor. Notwithstanding, the results of the study could be used in a cost-benefit analysis. Furthermore, the methodology could be used for ambulance services elsewhere.

As noted by Blanchard et al. [1], there are not so many studies on the relationship between the response time of emergency medical service and the saving of lives. The results have been mixed. When it comes to cardiac arrest, reducing ambulance response time has been shown to increase the survival rate [2–4]. Gonzales et al. [5] found increased emergency medical service prehospital time to be associated with higher mortality rates, as did Wilde [6] and McCoy et al. [7] recently. Fire and rescue services have been found to increase the survival rate when having shorter response times than traditional ambulances for health care responses [8–10]. Newgard et al. [11], however, recently concluded that there is no relationship between the response time and outcome of the patient, as other studies have also done before [12–14].

There are five motivations behind this article. The first is that, as noted above, there is not much research done on the effect of the response time. The second is that most of the studies mentioned have taken up one health problem (cardiac arrest), while from a planning perspective there are, of course, many more reasons for having ambulance services. Furthermore, most of the analyses have evaluated the 8-minute response time goal for American advanced life support units responding to life-threatening events. This study focuses instead on a continuous

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measure of the response time. The third is that this analysis examines not only the relationship between response time and mortality but also the effect of the illness condition for non-mortality cases. The fourth is that the number of observations in this study is more than a million compared with hundreds or thousands in the articles mentioned above. The fifth is that this analysis does not stop at the outcome of the patient, but instead takes on an economic perspective, in which the purpose is to find a monetary value for the total benefits of reducing the response time. No similar cost-benefit study has been found, and there have been very few economic studies of out-of-hospital emergency care [15].

To find the monetary value of the time factor for emergency responses in Thailand, the analysis was done using an estimation procedure involving two major steps. The first step was to analyze the emergency response data in Thailand using logistic regressions. The dependent variables are fatality, severe injury, and slight injury. The independent variable is the response time or the operational time, where response time is the time from when a call is received until the response team arrives at the emergency scene and operational time is the time from when a call is received until the patient is admitted to a hospital. Holding other independent variables and risk factors constant, the marginal effect describes the increase or decrease in the time factor for a 1-minute change and how this will affect the risk of fatality, severe injury, and slight injury. In the second step, the perceived marginal effects from the first step are multiplied with monetary values of fatality, severe injury, and slight injury. Extrapolated to a loss value for the whole of Thailand, the value would be 2.2 billion Thai baht for response time and 1.1 billion Thai baht for operational time. These figures represent the positive welfare effect, for 1 year, of reducing the emergency response time in Thailand by 1 minute on average.

The second section describes the Thai emergency system and the data used. The model and the results are presented in the third section and the fourth section, respectively. The last section concludes the study with a discussion.

Data

The emergency call number "1669" is being introduced as the emergency medical contact number in Thailand. Up to now it has been common to call directly to a hospital. A dispatcher controls the resources by using different types of ambulances including the first response unit, the basic life support unit, and the advanced life support unit. The monitoring and implementation reports are created by extracting relevant data and information from the online-dispatch system called the "Narenthorn Emergency Medical Database" administrated by the Emergency Medical Institute of Thailand. The reports in the system include not only basic information on the dispatch center, location, and notification, but also time information and information about the injury, such as the time the information is received, the command time, the vehicle dispatch time, the scene arrival time, the scene departure time, the hospital arrival time, the base returning time, the total response time, the distance (in kilometers), and the type of ambulance.

The information on accident or emergency injury is categorized into 12 items (for disaster into 6 items). Information of the injury is also categorized on the basis of seriousness levels and type of ambulance. The reports include information on the preliminary operation results on scene categorized by the type of treatment and identified by the referral, for example, death and no treatment, heart attack, and onsite treatment. The hospital treatment consists of admission time, treatment duration, treatment result, referrals, continuous treatment, death, and so forth.

In this study, response time and operational time are used and defined as follows: The *response time* is the time from when the call taker receives the phone call until the operational unit arrives at the scene site. The *operational time* is the time from when the call taker receives the phone call to the operational unit transfer of the patient to the hospital.

The Narenthorn database has been used nationwide and covers the regions with about three fourths of the population of Thailand (eight provinces not included). For the period studied here, 2009 to 2010, there are 1,489,800 reports. There are qualitative problems, however, with the reports from October 1, 2009, to March 31, 2010, because some obviously contain wrong time data. In total, only 1,186,067 reports are used in the analysis (see the next section).

Treatment results are categorized into four levels: no injury, slight injury, severe injury, and fatality. *Slight injury* means patients who receive medical care on scene and are not transported to hospital, or are transported to the hospital, but are not admitted to a hospital. *Severe injury* means patients who receive medical care, are admitted to a hospital, and when there is no death before or after the rescue services arrive on the scene, or after the patients receive emergency care. *Fatality* means patients who die before or after the rescue services arrive at the scene, or after the patients receive emergency care, and includes death at the hospital. No injury is used when no other criteria is met.

The cause of the incident is divided into four groups: physical trauma, medical emergency, traffic accident, and others. Physical trauma includes falling and collapsing, fall from a height, building collapse, physical assault, other traumas, fire, electrocution, burns, bombing, natural hazards, and hazardous materials. Medical emergency includes drowning, suicide, and medical emergency, while traffic accident includes motor vehicle collision.

In Figure 1, we can see the relationship between the response time variable and the percentage of death and severe injury for all cases and for each emergency type. The risk of fatality increases up to a response time of 20 to 25 minutes, but after 25 to 30 minutes the curves seem to be quite horizontal and thus the risk of dying is no longer increasing. For severe injuries, the relationships have about the same shapes (not shown here).

The purpose of an economic cost-benefit analysis is to measure the welfare effects of public investments. If the benefits of the investment are larger than the costs, measured in monetary units, welfare can be increased by investing in the project. Therefore, we need figures in Thai baht for saving lives and reducing injuries.

There are two main methods of finding such monetary values: the cost-of-illness method and the willingness-to-pay approach. Willingness to pay is based on the idea that people can assess the risk of having an accident and that they will pay for reducing or minimizing that risk (see e.g., [16–18]).

When it comes to estimating the value of a statistical life, there have been only a few studies that cover Thailand [19–22], with values ranging from US $0.25 million to US $3.0 million. Another question is whether the same value should be used for different injuries; some studies have found different values depending on the context [23–26]. This fact, however, has not been taken into account in this study.

The above studies only calculate values of a statistical life. We are also interested here, however, in the monetary value of severe injury and slight injury. We therefore instead use results from a study that used a cost-of-illness method (see e.g., [27,28]) to calculate the cost of traffic accidents in Thailand in 2004. The Thai study [29] focused on five regional hospitals that had a department for providing service data on injuries caused by traffic accidents. The loss value for 2004 was also recalculated

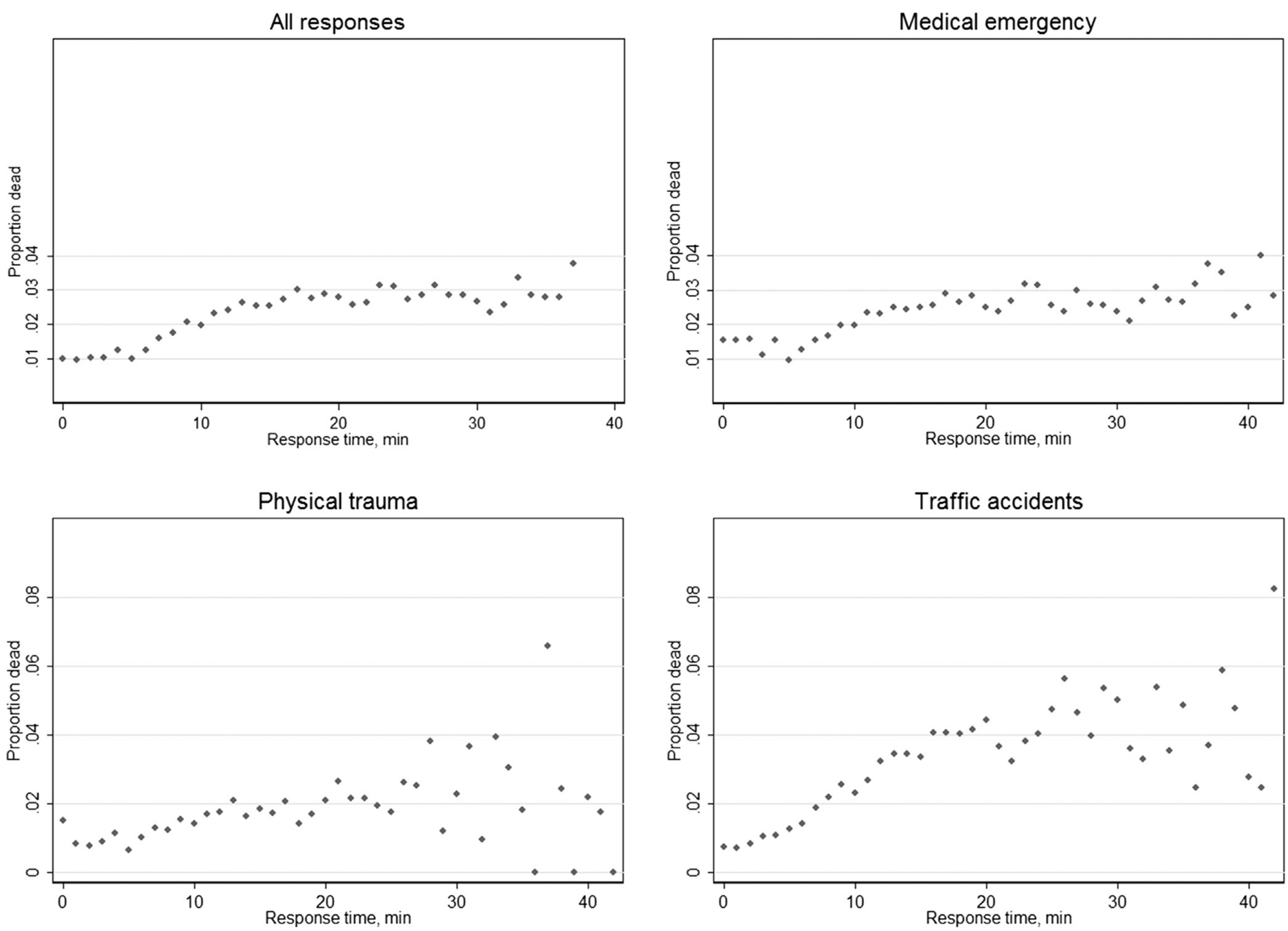

Fig. 1 - Proportion of deaths related to response time for different injury types.

to values of 63.3 million baht (=US $2.0 million, US $1 = 32 Thai baht in 2011) for fatality, of 59.0 million bath for severe injury, and of 1.3 million baht for slight injury for 2011 by adjusting for inflation (25%).

The Model

One problem is to find a model that both best fits the data and performs well in calculating the marginal effects of a change in response time. For an example of this, let us look at the relationship between response time and deaths in traffic accidents. Because there seems to be no change in proportions of deaths after about 25 minutes, one choice of a model is to restrict the data to only those dispatches in which the response time is less than or equal to 25 minutes. The difficulty with such a model is that it will predict a much higher proportion of deaths above 25 minutes than is reasonable according to the data. We can see that about 5% deaths is a reasonable figure for a response time of 40 minutes (Fig. 1). A logistic regression model that is restricted to

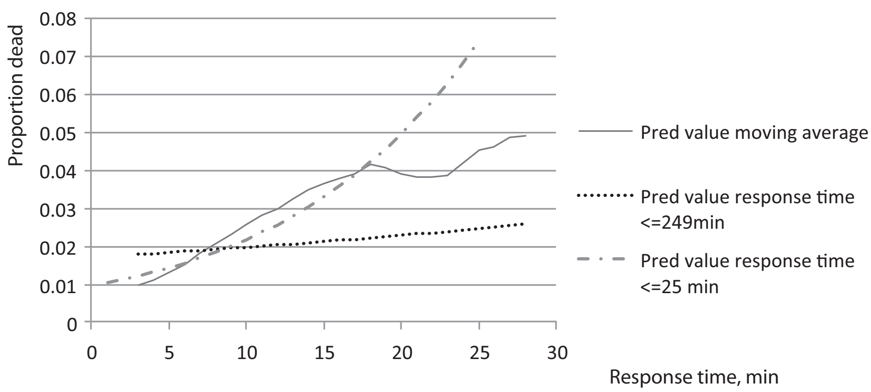

Fig. 2 – Proportion of deaths related to response time using different models.

Table 1 – Marginal effects and P(.) > 0 results for response time evaluated at median response time (=8 min).

Injury type/emergency type	Physical trauma	Medical emergency	Traffic accident	Others
Fatality	0.0001473 (0.000)	0.0001912 (0.000)	0.0002861 (0.000)	0.0000287 (0.309)
Severe injury	0.0027129 (0.000)	0.0040699 (0.000)	0.0017932 (0.000)	0.0047531 (0.000)
Slight injury	−0.0004476 (0.000)	−0.0002977 (0.000)	−0.001437 (0.000)	−0.0003409 (0.000)

less than 25 minutes, however, would predict this to be about 40% (Fig. 2). Another suggestion is to choose something such as a moving average logistic regression model, in which the first model includes data for only 1 to 5 minutes, the second from 2 to 6 minutes, the third from 3 to 7 minutes, and so forth. Predictions and marginal effects are then calculated for 3 minutes for the first model, 4 minutes for the second model, and so forth. Such a model fits the data much better, but it is not very general because it has different parameter values for each minute of response time. Yet another alternative is to try to include as many data points as possible. This is the approach used here, and all response times up to median time + one SD are included. What we are after is a value for a change of 1 minute in response time for an average dispatch, and we use this model even if it does not fit the data perfectly. The models thus contain response times up to 249 minutes and operational times up to 313 minutes. (The maximum time is chosen according to mean + one SD.) Because the relationship between the outcome and the response time seems to be somewhat different, depending on the case of the emergency, we have chosen to perform different statistical analyses for each case of emergency (traffic accidents, medical emergency, physical trauma, and others).

Estimation Procedure and Results

Four steps have been used. First, logistic regression models have been used to find parameter estimates for how the time variables affect the three injury types (Equation 1). α is the constant, and β is the regression coefficient for time in the inverse logistic or logit function. β shows how time affects the probability of injury. However, because the models are nonlinear, the β s cannot directly be interpreted as marginal effects. Equation 1 has been estimated for each injury and emergency type, and for response time and operational time, respectively; that is, 3 × 4 × 2 = 24 models have been estimated.

$$E(Y) = \text{Prob}(Y=1) = \frac{e^{\alpha+\beta * \text{TIME}}}{1+e^{\alpha+\beta * \text{TIME}}} \tag{1}$$

Second, the marginal effects are calculated using Equation 2. The marginal effects are evaluated at the median response time and median operational time. Normally, marginal effects are evaluated at the sample means [30]. However, because the median better describes the typical response time and operational time in the sample used here, the median has been used instead.

$$\text{Marginal effect} = \frac{\partial E(Y)}{\partial TIME} = \frac{e^{\alpha+\beta * \text{TIME}}}{(1+e^{\alpha+\beta * \text{TIME}})^2} \tag{2}$$

The marginal effects for response time are presented in Table 1. They are higher for severe injury than for fatalities, meaning that a marginal decrease in response time leads to more people saved from severe injury than from fatality. For fatality, the marginal effect is highest for traffic accidents, while for severe injury it is highest for others followed by medical emergency. For slight injuries, the marginal effects are negative and will therefore not be used in the next step. For operational time (not showed here), the marginal effects are lower than for response time, indicating that there is a decreasing marginal value of time because the operational time is longer than the response time.

Third, the marginal effects have been recalculated into the number of persons affected by a 1-minute change in response time and operational time in 1 year, as presented in Table 2. If the marginal effect is not statistically significant or negative, the value is set to zero. A 1-minute change would save most people from fatality when it comes to traffic accidents. For severe injuries, a 1-minute change would save most in the treatment group others, followed by medical emergency.

Fourth, the monetary values have been summed up in Thai baht (฿), for 1 year, for each emergency type and totally for all emergency responses (Table 3). For both response time and operational time, the most important treatment type is medical emergency, followed by traffic accident. The values for operational time are lower than the values for response time, reflecting the decreasing marginal value of time. Different ambulance types have different marginal benefit values per minute. For response time, advanced life support has a value of 1130 baht/min, basic life support a value of 644 baht/min, and first response a value of 445 baht/min; that is, the more advanced the ambulance is the more important is the response time.

The loss values for a 1-minute improvement in the time factor for 1 year have been calculated using the provinces in the

Table 2 – Deaths and injuries saved per year calculated given marginal effect per minute for response time and operational time.

Injury type/emergency type	Physical trauma	Medical emergency	Traffic accident	Others
Response time				
Fatality	11.9	15.5	23.2	2.2
Severe injury	220.0	330.0	145.4	398.3
Slight injury	0	0	0	0
Number of dispatches	81,101	423,356	226,215	18,424
Operational time				
Fatality	8.8	8.7	17.0	–
Severe injury	88.5	109.8	51.4	136.5
Slight injury	0	0	0	0
Number of dispatches	81,101	423,356	226,215	18,424

Table 3 – Monetary value (฿) per minute and year.

Baht/y/min/emergency type	Physical trauma	Medical emergency	Traffic accident	Others	Total
Response time (at median 8 min)	135,401,000	987,186,000	484,352,000	27,349,000	1,634,289,000
Operational time (at median 24 min)	76,177,000	427,974,000	304,957,000	9,370,000	818,477,000

Narenthorn database. Eight provinces are not included in the database, representing 26.8% of the total number of emergency responses. Extrapolating to whole Thailand gives a value of 2.2 billion Thai baht (= US $69 million) for response time and 1.1 billion Thai baht for operational time.

As an example, assume that an investment was made in a new call-taking and dispatch system that could decrease the response time and the operational time by 1 minute. Using the results from this study, assuming a technology life of 20 years, and a social interest rate of 6%, the present value of the benefits of such an investment is between 12.8 and 25.6 billion Thai baht.

Discussion

The results show that the time factor is most important for medical emergency, followed by traffic accidents and physical trauma. They also show that the more advanced the ambulance the more important is the response time.

One limitation of the study is that the emergency response data cannot categorize permanent disability as a final outcome; thus, the additional loss value of disability is excluded in the analysis, and the loss value for those cases is covered under the category of severe injury.

The planned investment thought of here is a better alarm system that could reduce the time from accident or injury to dispatch of ambulance and result in a 1-minute decrease in response time. In comparison, a study in Canada showed that the introduction of base paging reduced the call-response interval by 30 seconds [31]. Considering operational time, Spaite et al. [32] noted that operational problems occurred in more than 40% of the dispatches. Another way to decrease time is to enforce a single alarm number (as in the European Union, 112, or North America, 911) instead of the different numbers to police, fire and rescue services, and emergency response, together with dialing directly to hospitals for ambulance, as is used in Thailand now. Thus, there seems to be possibilities for increased effectiveness. High-speed driving could perhaps be the solution to faster response time in rural areas [33], but probably not in populated areas; and using lights and sirens when driving ambulances has both pros and cons such as the high risk of crashes [34,35].

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